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Durability of laser fibers

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Summary. In 90 patients treated with laser prostatectomy using the Urolase ($n = 50$) or Ultraline ($n = 40$) laser fiber, the fiber-tip durability was investigated. In general the Urolase fiber tips were less damaged than the Ultraline fiber tips. At visual inspection, 62% of the Urolase fiber tips were graded as minimally damaged in comparison with 28% of the Ultraline group. The Urolase fiber tips are more susceptible than the Ultraline fiber tips to damage caused by tissue contact, whereas the latter seem more fragile. Transmission measurements were performed in a laboratory setting to estimate the loss of energy output at the fiber tip due to damage. These measurements showed a major loss in almost all fibers. None of the Ultraline fibers had less than 10% transmission loss, and 18% of the Urolaser fibers had a transmission value of more than 90%. Finally, there seemed to be a poor correlation between the visual aspects of the fibers used and the changes in transmission.

Benign prostatic hyperplasia (BPH) has a high prevalence in men over 50 years of age. Almost 50% of men with macroscopic BPH will develop voiding complaints, and the majority of these men will eventually require surgery [1]. For more than 60 years, the "gold standard" of surgical therapy for this problem has been transurethral electroresection of the prostate (TURP). Although the mortality has been reduced from 2.5% to 0.2% over the past 25 years, the morbidity has remained unchanged at 18% [2]. Because of this rather high morbidity, many (minimally invasive) alternative treatment methods were introduced during the last decade, such as medical management, balloon dilatation, prostatic stents, hyperthermia, and thermotherapy. Although the morbidity has decreased, these alternatives have not been capable of replacing TURP because none of these methods has thus far reached the same results as TURP.

Following the canine feasibility studies of Johnson et al. in 1991 [3] and the first laser prostatectomies performed with a side-firing device in men by Costello et al. in 1992 [4], the laser was introduced for the treatment of symptomatic BPH. Recent reports show that the results of laser prostatectomy are comparable with those achieved after TURP [5–9]. However, laser treatment also has its limitations. Except for the contact devices currently under investigation, during the procedure the amount of tissue destruction cannot be controlled accurately by the surgeon. A factor associated with tissue destruction is the amount of energy delivered to the prostate that will eventually be absorbed by the prostate gland. This depends on a number of variables, such as reflection of laser light, changes in tissue characteristics during lasing, tissue cooling via increased prostatic blood flow, the color of the prostate, and loss of power output due to fiber-tip decrease during the laser procedure. The present study was performed to investigate the posttreatment decrease in the quality of the laser fibers currently used at our department.

Materials and methods

Laser prostatectomy was performed with the Urolase or Ultraline fiber. The techniques used have been described extensively in an article by de la Rosette et al. (this issue). After the treatment, the energy delivered by the laser source was noted, and the laser fibers were cleaned with a swab and sterile water. To assess the effect of laser prostatectomy on the quality of laser fibers we visually examined the fibers used. The fiber tips were independently inspected by two observers involved in the performance of the laser treatment, who graded the fiber tips on a scale ranging from 1 to 5 according to the degree of damage to the fiber tip (1, undamaged; 5, severely damaged; Fig. 1). The grades given by the two observers were added up and the result was considered the score for a particular fiber.

Transmission measurements to assess the percentage of energy loss were performed in a laboratory setting developed by the Department of Physics. The setting consisted of a power source, a LED (light-emitting diode), producing light with a wavelength near that of Nd:YAG laser light; a coupling device to connect the fiber; an especially developed cylinder in which the fiber tip just fits; and an electric eye in the cylinder connected to a power meter to measure the output from the fiber tip (Fig. 2).

Each fiber was connected to the power source and the fiber tip was then introduced into the cylinder. The electronic eye in the cylinder was situated close to the fiber tip for optimal registration of the fiber output. The fiber was manipulated by hand to produce the position with the maximal power output. The energy input was set at 5 mW. We fist performed the measurements on new fibers and these results were used as baseline values. Thus, the transmission measured in used fibers are expressed as a percentage of that noted in a new fiber. These measurements were also done independently by the two investigators.

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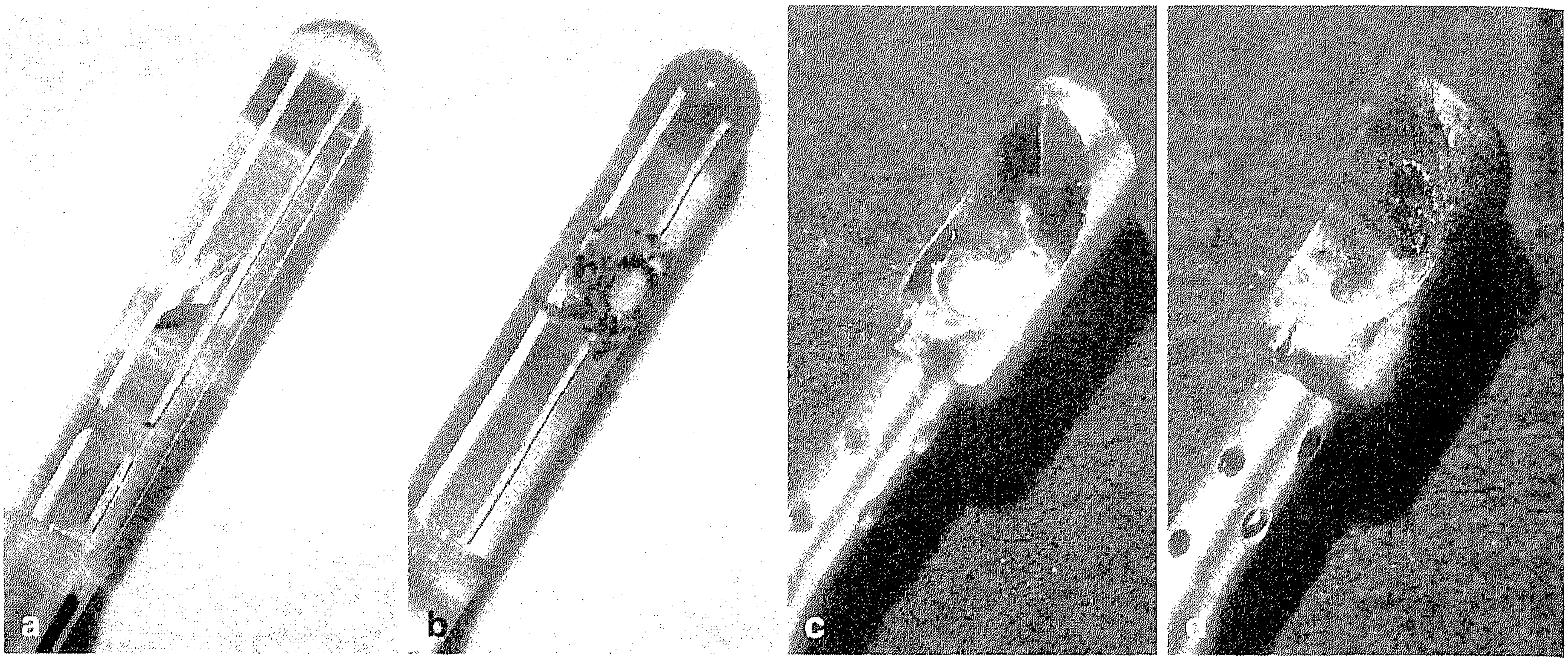

Fig. 1a–d. Visual aspects of the laser fibers. a New Ultraline fiber. b Severely damaged Ultraline fiber. c New Urolase fiber. d Severely damaged Urolase fiber

Results

Visual aspects

The Urolase fiber tips were less affected than the Ultraline fibers tips. In the Urolase group, 31 fibers (62%) were graded as minimally damaged in comparison with fibers (28%) in the Ultraline group. Moreover, the Ultraline fibers appeared to be more fragile; 9 of the 40 fibers were broken at the tip during or after the laser procedure. On the other hand, 6 Urolase fibers (12%) were severely damaged, frequently due to direct contact with the prostate tissue resulting in burning of the fiber tip. Severe damage was found in only 2 Ultraline fibers (5%). The majority of the fibers showed the same result at inspection by the two investigators (Table 1).

Transmission measurements

Overall, the Urolaser fibers had less transmission loss than the Ultraline fibers (Table 2). None of the Ultraline fibers had less than 10% transmission loss, whereas 9 of the 50 Urolase fibers (18%) had a transmission value of more than 90%. Only in 5 Ultraline fibers (13%) was the transmission above 80% as compared with 20 Urolase fibers (40%). For both fibers we could not find a relation

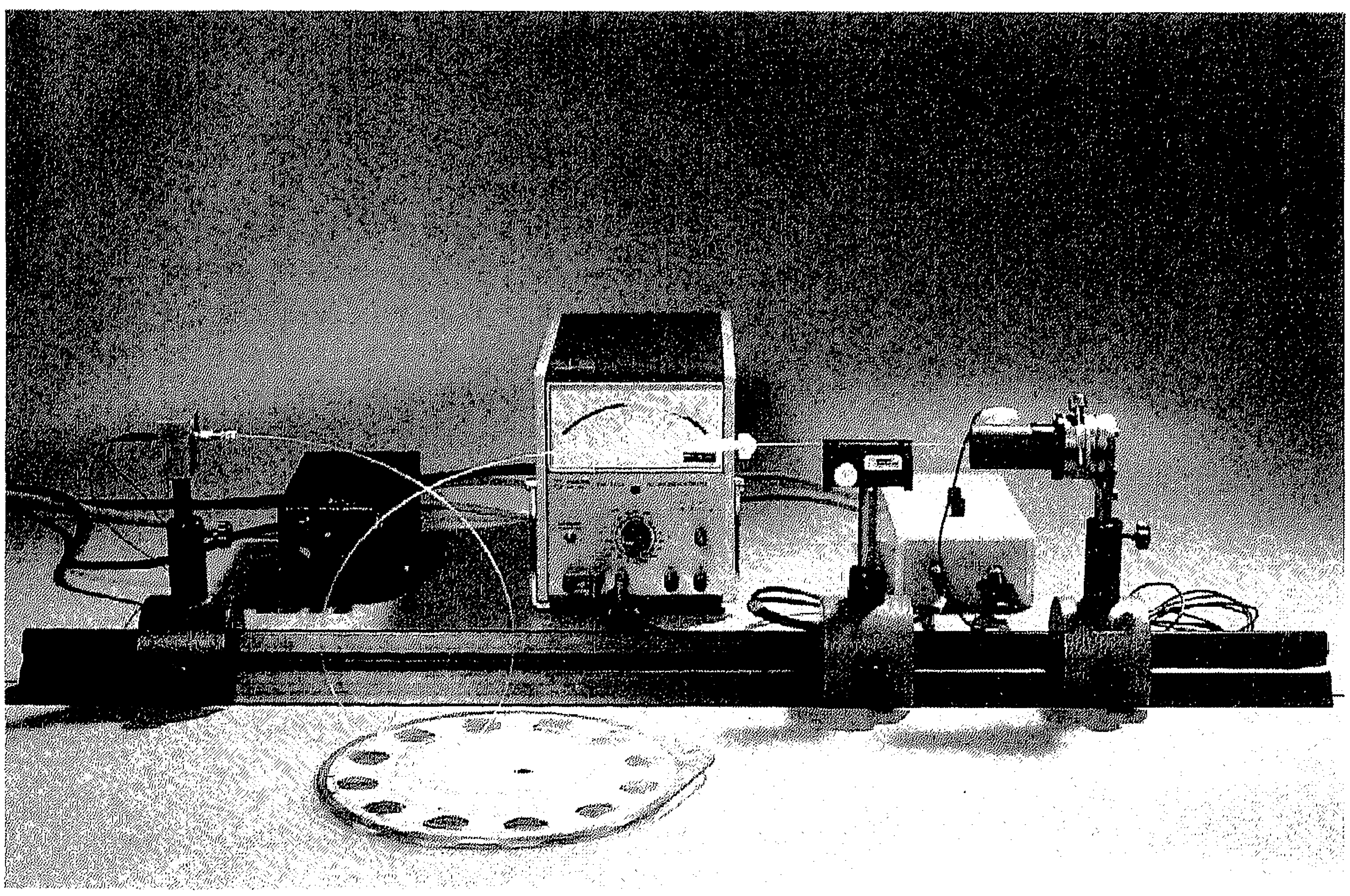

Fig. 2. Laboratory setting used to perform the transmission measurements

Table 1. Presentation of the visual aspects of the laser fibers used versus the number of fibers in each subgroup

Fibertip	Damage	Urolase ($n = 50$)	Ultraline ($n = 40$)
Grade 2–4	None–minimal	31	11
Grade 5–7	Moderate	13	18
Grade 8–10	Severe	6	2
Defect		0	9
Same	Grade	38/50	24/31

Table 2. Presentation of the loss of transmission and the number of patients in each group

% Transmission	Urolase (n)	Ultraline (n)
> 90	9	0
> 80	20	5
> 70	27	9
> 60	36	16
> 50	38	24

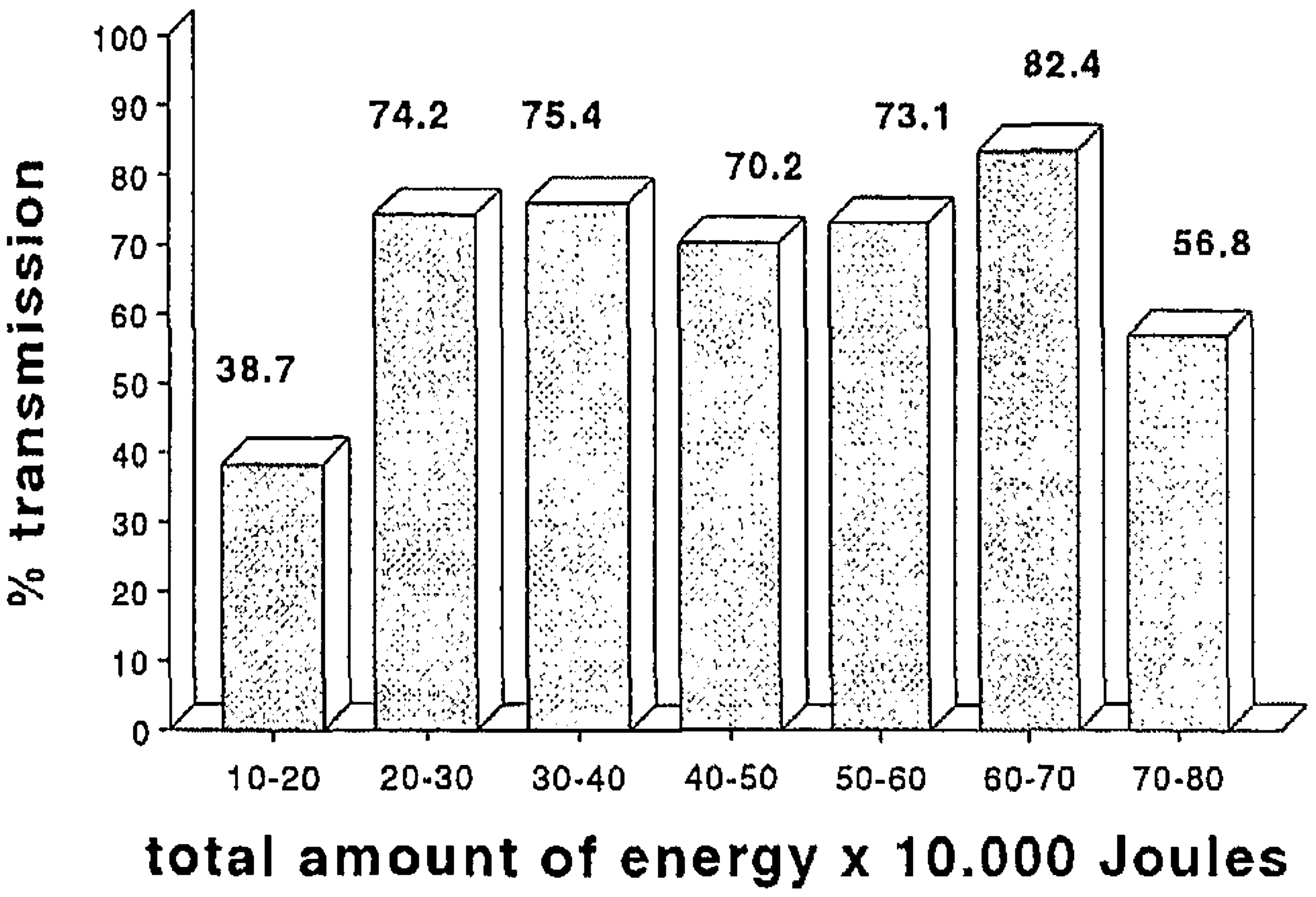

Fig. 3. The relation between the amount of energy delivered and the loss of transmission for the Urolase fiber

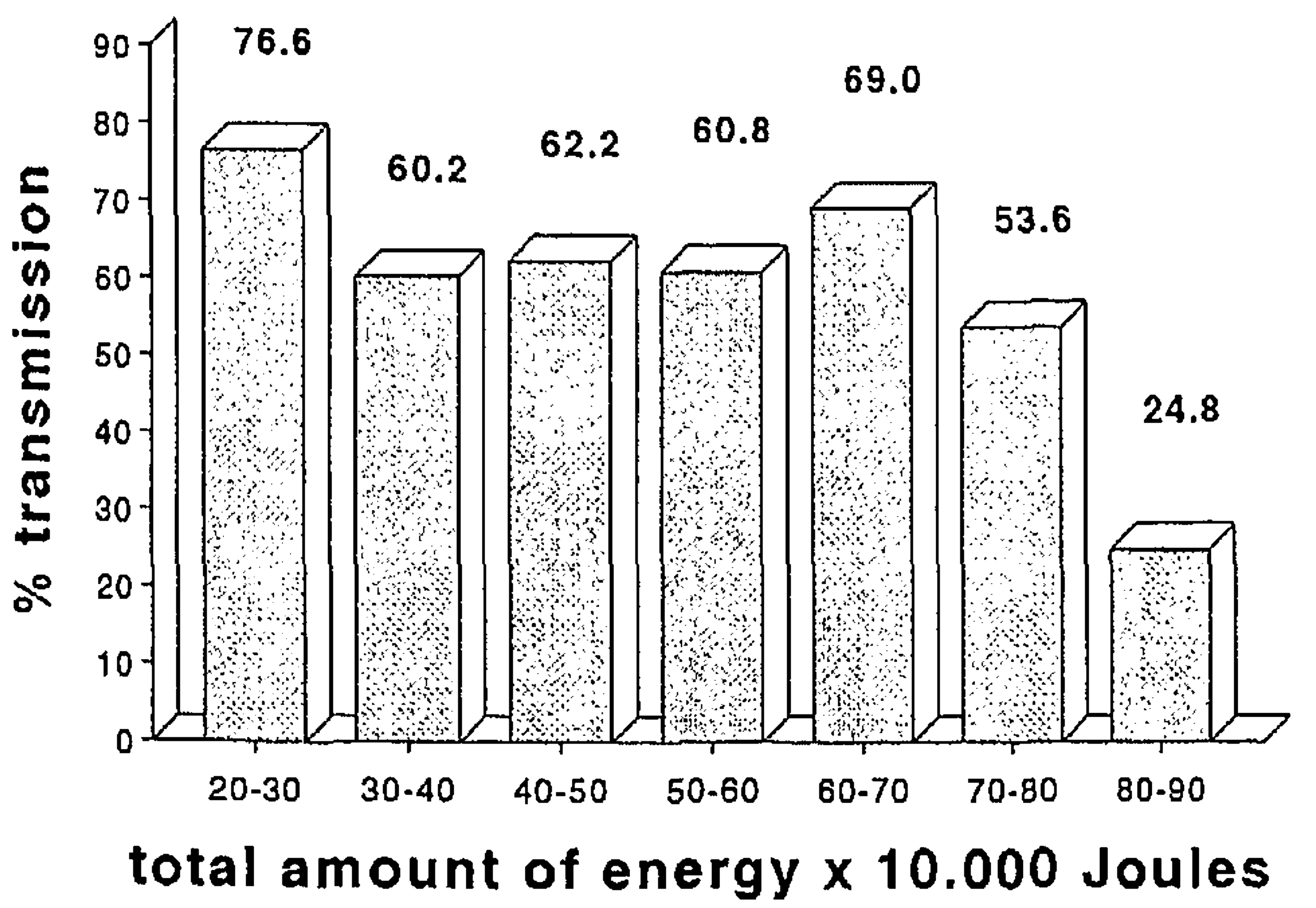

Fig. 4. The relation between the amount of energy delivered and the loss of transmission for the Ultraline fiber

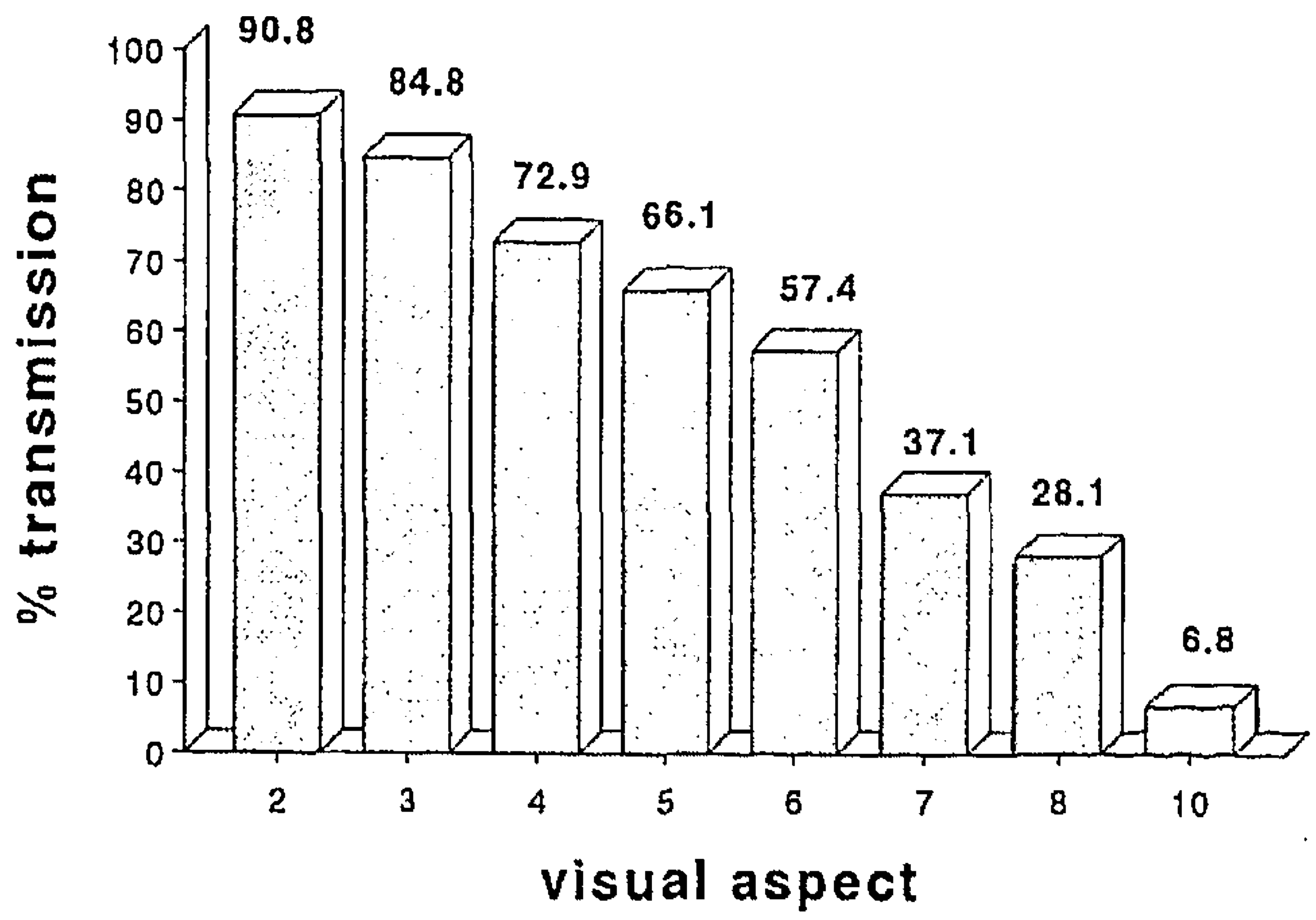

Fig. 5. The relation between visual aspects of the Urolase fiber and the loss of transmission

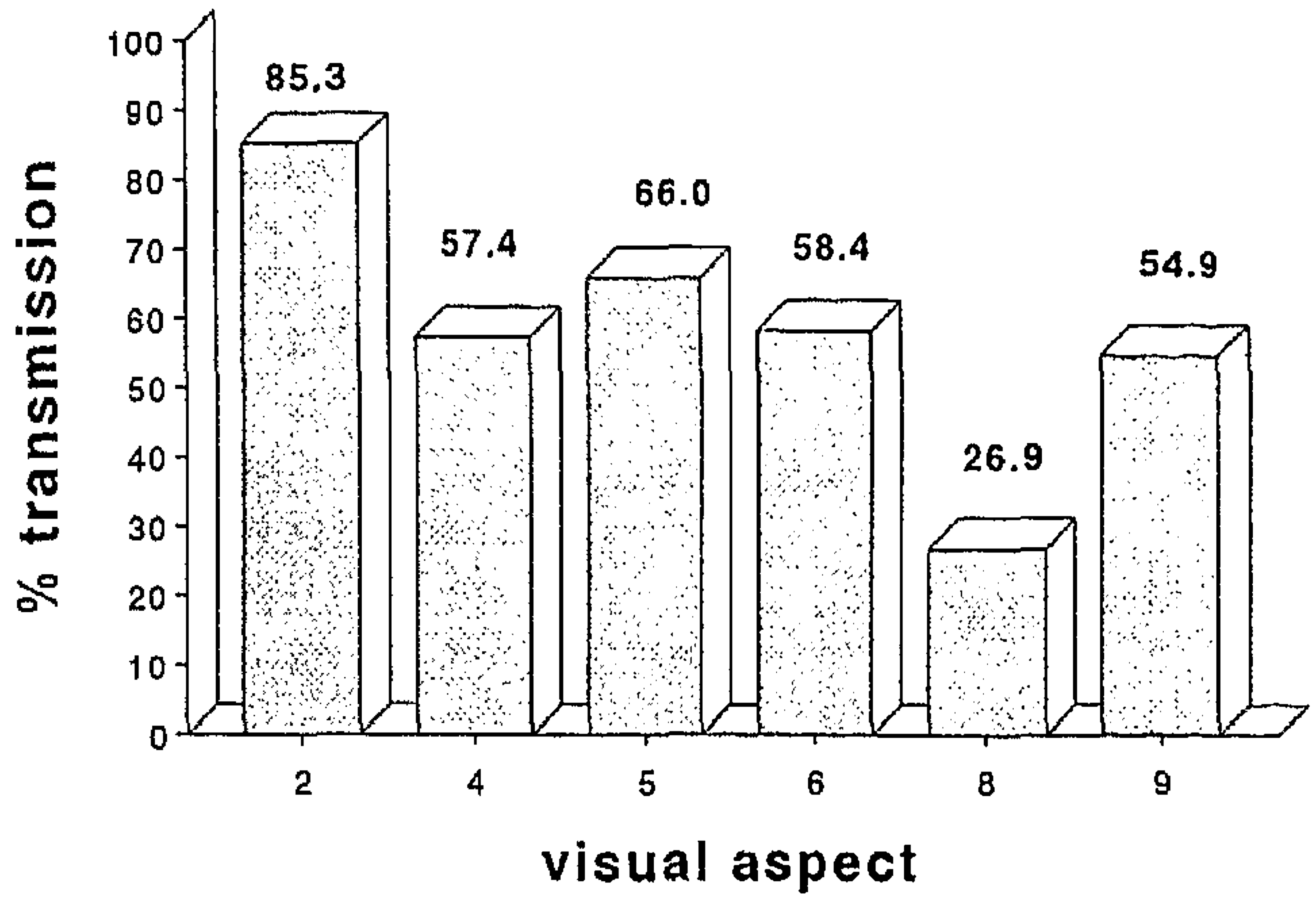

Fig. 6. The relation between visual aspects of the Ultraline fiber and the loss of transmission

between the amount of energy delivered through the fiber and the loss of transmission (Figs. 3, 4). On average, 50–60 kJ was delivered to the prostate, resulting in a transmission value of 60%–70% at the end of treatment, depending on the type of fiber used.

There seemed to be a correlation between the visual aspect of the Urolase fibertip and the loss of transmission, but the variation was too great for conclusions to be drawn for a given single fiber. A similar correlation for the Ultraline fibers was not detected. The majority of the Ultraline fiber tips showed moderate damage that did not seem to be correlated to the level of transmission (Figs. 5, 6).

Discussion

The Nd:YAG laser achieves the deepest tissue penetration of all available surgical lasers, and its energy is selectively absorbed by tissue proteins, causing deep thermal necrosis and resulting in tissue ablation. It is only natural, then, that use of the Nd:YAG device for laser prostatectomy should be explored. Many different laser fibers are appearing on the market for treatment of BPH. The (non)contact laser fibers, such as the Urolase and Ultraline fibers, redirect the beam laterally so as to allow better tissue ablation. However, there is no reason to assume that these fibers are equivalent. The redirecting mechanisms include highly engineered reflecting mirrors (e.g., the Urolase fiber) or quartz refractive prisms (e.g., the Ultraline fiber). The beams are deflected at various angles and the spot size differs from one fiber to the next. In the ideal setting, the amount of energy delivered to tissue is, among other factors, determined by the power setting (watts) and the length of time over which the beam is activated (seconds). The product of these two parameters is the amount of energy delivered and is measured in joules. In most situations it is impossible to determine specifically how much energy has been absorbed.

The optimal Nd:YAG power setting, time for energy delivery, and type of applicator for laser treatment remain under investigation. Some power transmission is lost in the bending mechanism, and this varies depending on the efficiency of the process used. The dosimetry protocols for the devices are rather similar, although the devices themselves vary significantly as to the power density at the urethral wall. From studies by van Swol et al. [10] we have learned that the optical characteristics of the devices may differ significantly, mainly due to the method of beam deflection. It was concluded that besides the prostate geometry and the blood perfusion, the power density at the urethral wall should be taken into account in the dosimetry for an effective BPH treatment. Shanberg et al. [11] presented a study determining the depth of penetration of the laser in the human prostate at varying dosimetry. Using the Prolase II laser fiber, their data indicated that for this type of fiber there appeared to be an optimal power setting and pulse duration for the greatest depth of penetration. Kabalin [9] has shown that for the Urolase fiber the 40 W, 90 s setting provides optimal results for laser prostatectomy.

However, before laser energy is applied to the prostate, it must be transmitted from the laser source by the laser fiber. The present study shows that a difference in transmission measurements can be found for the two fibers tested. None of the Ultraline fibers had less than 10% transmission loss, whereas almost 20% of the Urolase fibers had a transmission value of over 90%. Therefore, we may conclude that the Urolase fibers seem more durable than the Ultraline fibers. We were somewhat surprised by this result, as we assumed that the Urolase fiber would be more fragile because contact with prostate tissue easily damages this device. On the other hand, the observed damage to the Ultraline fibers may be explained by the observation that this fiber was also used in contact. This may eventually result in growth of particles on the fiber tip, causing a decrease in these laser fibers. The effect of this process is difficult to judge in terms of the quality of the laser fiber posttreatment. The correlation between the visual aspect of the Ultraline fibertip and the transmission was poor. In contrast with these findings were the results obtained in the Urolase group. There appeared to be a good correlation between the visual aspect of the Urolase fibertip and the loss of transmission. Consequently, one may decide to use a second fiber if the visual aspect of the Urolase fiber looks poor, whereas it is more difficult to judge the quality of the Ultraline fiber. Moreover, we must stress that a normal visual aspect of the tip of a given fiber does not guarantee that the quality of the fiber is good. Therefore, it may be important to measure the loss of transmission during laser treatment.

The system described in the present study was used with a low power input. We realize that it would be ideal to perform these studies at 40 or 60 W, but this would make the measurements more difficult to perform. The currently used method is simple, reproducible, and easy to perform. The outcome of these measurements represents the minimal loss of transmission; thus, at higher power settings the loss may be much greater.

Although the outcome of the transmission measurements show major differences for the two fibers used, the clinical results are more or less similar. We think that because use of the Ultraline fiber involves a higher power setting and a smaller beam, this may compensate for the loss in transmission and result in a more or less identical power density.

Thus, considering the variety of devices available at present, one would expect these to differ in terms of response and outcome. To our surprise, the results achieved with the fibers used in the present study were similar (also see the article in this issue by de la Rosette et al.). One may come to the conclusion that it is the general effect of laser energy on tissue that is most important rather than the device or technique used. However, the degradation of the fiber tip may not be reflected in the results achieved over the short term but may differ significantly in the long term. Therefore, we think that efficacy studies should determine not only fiber characteristics but also fiber durability. If the fiber performance is being tested during the treatment, the investigator may decide to increase the power input or to replace the laser fiber.

In conclusion, laser ablation of the prostate represents an exciting potential application of laser technology. The optimal technique as well as technology are clearly evolving and the efficacy of various side-firing devices for the treatment of BPH is under investigation. A difference in durability was found between the two fibers tested. Therefore, future studies should consider measurement of fiber durability and correlate these findings with the outcome of treatment and the long-term follow-up results.

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